International Journal of Mechanical and Production Engineering Research and Development (IJMPERD)
ISSN (P): 2249-6890; ISSN (E): 2249-8001
Vol. 8, Issue 1, Feb 2018, 445-456
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EVALUATION OF ENGINEERING PROPERTIES OF FLEXIBLE PAVEMENTS USING PLAXIS SOFTWARE

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ABSTRACT

This research work focus on evaluation of geotechnical and engineering properties of a flexible pavement using Plaxis software and design parameters of this pavement were considered as per code IRC: SP: 72-2007 guide lines for design of low volume rural roads of flexible pavements. These pavements layers were tested by applying different test loads of 5KN and 10KN in Plaxis software generally the acceptable test load for low volume flexible pavement as per the code IRC: SP: 72-2007 guide line is 3KN. The output generated by the software gives the engineering properties of the pavement such as deformation, displacement, stress and strain conditions.

KEYWORDS: Engineering Properties, Geotechnical Properties, Plaxis Software, Deformation, Deflection, Stress & Strain Conditions

Received: Nov 22, 2017**; Accepted:** Dec 13, 2017**; Published:** Jan 08, 2018**; Paper Id.:** IJMPERDFEB201850

Original Article

INTRODUCTION

This paper attempts to understand and investigate the variations in sub-soil type and profiles to determine the geotechnical and engineering characteristics of the underlying soils by CBR test with moisture contents. Thus, various soil samples with different densities and moisture content were calculated. Detailed analyses of results were carried out.

The main characteristics of low volume rural roads that set them apart from more conventional highways are:

Rural road connectivity is important key component of rural development by promoting access to economic and social services and thereby generating increased agricultural incomes and productive employment opportunities in India.

The development of the rural road has a high potential to influence economic development through supply side effects.

Improvements in rural access typically give rise to benefits that arise from four sources:

- Lower transport costs to existing traffic due to smoother and sometimes shorter routes.
- Savings in time due to faster travel.
- Economic development benefits resulting In generated (new) traffic and
- Social benefits due to improved access to schools, hospitals, etc

LITERATURE REVIEW

The initial cost plays a major role in deciding type of the pavement and its design. Generally it is true that the cost of construction of flexible pavements is cheaper than rigid pavements but sometimes there may be some exception to this notion. The cost of construction material required for construction of flexible pavements is increased in global scenario of fluctuating prices.

Various aspects have made an extensive study on the design of flexible pavements in various aspects.

Goliya et. al (2013) has made an extensive study on flexible pavements and concluded that flexible

Pavements are better rigid pavements as roads since there is a greater flexibility for strengthening and improving the stages of flexible pavements.

Brushaspathi (2012) concludes the modern designs methods adopted in the construction of flexible pavements would improve the file and serviceability and reduce the cost of construction and maintenance.

Nantung et. al. (2008) concludes that the substantial data regarding traffic volume, loads of various parameters will definitely help to design a flexible pavement with efficient and effective engineering properties.

MATERIALS USED AND EXPERIMENTAL PROCEDURE

- Sieve Analysis: A sample of approximately 1000grams was used for the test after washing and oven-dried. The sieving was done by mechanical method using automatic shakers and a set of sieves.
- Liquid Limit Determination: A liquid limit the sample is determined by using Casagrande apparatus.
- CBR test on different soil samples under different moisture contents over varying days of soaking was tested.
- Aggregate Crushing Value: Two tests were conducted aggregates crushing value is determined by passingthe sample through 12.5mm and retained on 10mm IS Sieve are oven-dried at a temperature of 100 to110 o C for 4hrs and cooled.
- Aggregate impact value test: The mean of two observations, rounded to nearest whole number is reported as the aggregate impact value.
- Bitumen penetration test: To calculate the consistency of bitumen a penetration was carried out using standard penetrometer.
- 7. Ductility test of Bitumen It gives a measurable adhesive property of bitumen and its ability to stretch.

ANALYSIS OF RESULT

Table 1: Result of Sieve Analysis

S. No.	I S Sieve	Particle Size d(mm)	Weight Retained (g)	% Retained	Cumulative % Retained	% Finer n
1	100	100	0	0	0	100
2	63	63	0	0	0	100
3	20	20	0	0	0	100
4	10	10	26	2.6	2.6	97.4
5	4.75	4.75	0	0	2.6	97.4
6	2	2	136	13.6	16.2	83.8
7	1.18	1.18	208	20.8	37	63
8	0.6	0.6	355	35.5	72.5	27.5
9	0.425	0.425	130	13	85.5	14.5
10	0.3	0.3	40	4	89.5	10.5
11	0.15	0.15	12	1.2	90.7	9.3
12	0.075	0.075	6	0.6	91.3	8.7
	Pan					

Table 1: Representing the Details of Sieves Having Larger Opening Sizes are Placed Above the Ones Having Smaller Opening Sizes

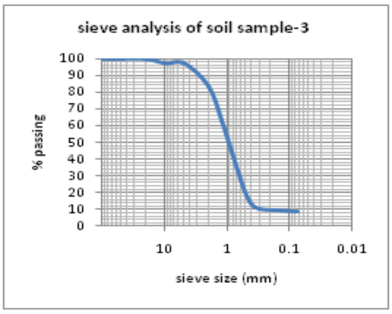

Figure-4 Represents graph of log sieve size vs % finer the graph is known as grading curve. Corresponding to 10%, 30% and 60% finer, obtain diameters from graph these are D_{10}, D_{30}, D_{60}, using these obtain Coefficient of curvature Cc and Coefficient of uniformity Cu which further represent how well the soil is graded i.e. whether the soil is well-graded, gap-graded or poorly graded

Table 2: Represents the Values of Coefficient of Uniformity and Coefficient of Curvature

Grain Size Distribution Curve Results:					
% Gravel:	**97.4**	**D_{10}:**	**0.3**	**C_u:**	**3.93**
% Sand:	**208.6**	**D_{30}:**	**0.6**	**C_{c}:**	**1.01**
% Fines:	**8.7**	**D_{60}:**	**1.18**		

Diameter of particle size

$D_{10} = 0.3$

$D_{30} = 0.6$

$D_{60} = 1.18$

Coefficient of curvature Cc = $\frac{(D30)^2}{(D10*D60)}$

$$Cc = \left(\frac{(0.6)^2}{0.3 * 1.18}\right)$$

$$Cc = 1.01$$

Coefficient of uniformity $Cu = \frac{D60}{D10} = 3.93$

According to the USCS Soil Classification system, the sample was poorly graded sand, gravelly sand, with little fines.

Table 3: Result Analysis of Liquid Limit Test

S. No	Determination	Sample1	Sample2	Sample3	Sample4	Sample5
1	Weight of container + wet soil(gm)	47.76	49.13	47.53	47.77	48.14
2	Weight of container + dry soil(gm)	37.23	38.18	37.19	37.78	38.18
3	Loss of moisture	10.53	10.95	10.34	9.99	9.96
4	Weight of container (gm)	14.893	14.72	14.58	15.55	15.53

Table 3: Contd.,						
5	Weight of dry soil (gm)	22.337	23.45	22.60	22.23	22.64
6	Moisture content	33.03	31.82	31.38	31.00	30.54
7	Number of blows	35	30	26	24	20

Table 3 Representing the Details on Calculations of Liquid Limit Test for Five Soil Samples the Total Weight of Containers and Wet Soil

Table 4: Result Analysis of Plastic Limit Test

S. No	Determination	Sample1	Sample2	Sample3
1	Weight of container + weight of wet soil (gm)	41.00	38.007	37.925
2	Weight of container + weight of dry soil (gm)	34.34	33.387	33.585
3	Loss of moisture (gm)	6.66	4.62	4.340
4	Weight of container (gm)	15.773	14.156	16.580
5	Weight of dry soil (gm)	18.567	19.231	17.005
6	Weight of wet soil (gm)	25.227	23.851	21.345
7	Moisture content %	26.400	19.370	20.332

Table 4 Representing the Details on Calculations of Plastic Limit Test for Three Soil Samples the Total Weight of Containers and Wet Soil

Plasticity index = liquid limit – plastic limit = 31.38 – 22.034 = 9.346 < 10

Table 5: Result Analysis of California Bearing Ratio Test

S. No	Determination	Sample 1	Sample 2	Sample3
1	Weight of mould + compacted soil	4912	4307	4149
2	Weight of compacted soil (W_t)	2015	1828	1737
3	Wet density $\gamma_t = W_t/V$	2.015	1.828	1.737
4	Container number	1	2	3
5	Weight of container + weight of wet soil (gm)	81.48	88.65	82.78
6	Weight of container weight of dry soil(gm)	75.84	80.06	73.680
7	Weight of water(gm)	5.64	8.59	4.10
8	Weight of container(gm)	15.108	11.280	13.940
9	Weight of dry soil(gm)	60.732	68.780	59.740
10	Water content (%)	8.497	11.102	13.219
11	Weight of wet soil (gm)	66.372	77.37	68.84
12	Dry density(gm/cc)	1.857	1.645	1.534

Table 5: Calculations of California Bearing Ratio Test for Dynamic Compaction

Table 6: Representing the Calculations for California Bearing Ratio Test Values for the Three Samples

California Bearing Ratio Test											
Penetration in Mm	Proving Ring Reading no. Division				Corrected Load		Standard Load (kg)	% of CBR		Average cbr	
0											
0.5	4	5	4								
1	6	7	6								
1.5	8	7	9								

Table 6: Contd.,

2	10	10	9									
2.5	14	13	13	35	32	32	1370	2.5	2.3	2.3	2.4
3	15	13	14									
4	15	13	14									
5	16	16	15	80	80	75	2055	3.8	3.8	3.6	3.8
7.5	19	20	23									
10	24	23	25									
12.5	28	27	28									

Corrected load= (penetration in mm) x (proving ring readings)

Corrected load for sample 1 = 2.5 x 14=35

Corrected load for sample 2= 2.5 x 13=32.5

Corrected load for sample 3= 2.5 x 13=32.5

Now the percentage of California bearing ratio for all the samples is calculated as shown below for 2.5 mm and 5 mm penetration is placed in (column 5)

Percentage California bearing ratio =$\frac{\text{corrected load}}{\text{standard load}}$**X 100**

Standard loads of California bearing ratio test at 2.5 mm and 5 mm penetration

Percentage of California bearing ratio for sample 1 at 2.5 mm penetration =$\frac{35}{1370}$X 100 =2.55

Percentage of California bearing ratio for sample 2 at 2.5 mm penetration =$\frac{32.5}{1370}$X 100 =2.37

Percentage of California bearing ratio for sample 3 at 2.5 mm penetration=$\frac{32.5}{1370}$ X 100 =2.37

Finally the average California bearing ratio test value at 2.5 mm penetration is calculated by taking the mean of three samples and placed in (column 6)

Average California bearing ratio test value at 2.5 mm $=\frac{\mathbf{2.55+2.37+2.37}}{\mathbf{3}}$ **= 2.43%**

Percentage of California bearing ratio for sample 1 at 5 mm penetration =$\frac{80}{2055}$X 100 = 3.89

Percentage of California bearing ratio for sample 1 at 5 mm penetration =$\frac{80}{2055}$X 100 =3.89

Percentage of California bearing ratio for sample 1 at 5 mm penetration=$\frac{78}{2055}$ X 100 =3.64

Finally the average California bearing ratio test value at 5 mm penetration is calculated by taking the mean of three samples and placed in (column 6)

Average California bearing ratio test value at 5 mm = $\frac{3.89+3.89+3.64}{3}$ = **3.80%**

Result of California Bearing Ratio Test

If the California bearing ratio value for 5 mm penetration exceeds that of 2.5mm, the test should be repeated if identical results follow the California bearing ratio corresponding to 5 mm penetration should be taken for design so the

California bearing ratio test value of 5mm i.e.; **3.80%** is considered for designing of pavement.

Table 7: Result of Ductility Test

Ductility Test on Bitumen			
Bitumen source	S-65		
Test Temperature	27^0C		
Period of Cooling	In air 30 minutes		
Briquette No	**Initial Reading (a)**	**Final Reading (b)**	**Ductility (b-a)**
1	0	74.6	74.6
2	0	77.2	77.2
3	0	73.5	73.5
Average Values			**75.1cm**

Table 7: Represents the Ductility Test on Bitumen Sample of S-65 of Three Specimens Taken in Standard Mould

Interpretation and Reporting the Results

The distance at which the bitumen thread of specimen breaks and the mean of three observations rounded to nearest whole number is ductility value. For the given S-65 the ductility requirement is 75 cm According to the standards in Table 28 hence the experimental value for the S-65 is 75.1cm and it satisfies the condition.

Ductility Test of Bitumen $\frac{\mathbf{74.6+77.2+73.5}}{\mathbf{3}}$ = 75.1 cm

Table 8: Result of Softening Point of Bitumen

Calculations For Softening Point Test of Bitumen		
Bitumen source	S-65	
Observations	**First Ball**	**Second Ball**
Temperature at which the ball touches the bottom	46^0C	47^0C
Average Softening Point of Bitumen	46.5^0C	

Table 8: Representing the Calculations for Softening Point Test of Bitumen Source of Bitumen

Interpretation and reporting the results

Average Softening Point of Bitumen for the given S-65 bitumen source is 46.50C

Softening Point of Bitumen = $\frac{46+47}{2}$ = 46.50C

Table 9: Calculations for Penetration Test on Bitumen

Calculations for Penetration Test of Bitumen			
Bitumen source	S-65		
Test Temperature	25^0C		
Penetrometer Dial Reading	**Test 1**	**Test 2**	**Test3**
Initial reading	220	288	350
Final reading	288	350	410
Penetration Values	68	62	60
Mean Penetration Values	**63.33**		

Table 9: Representing the Calculations for Penetration Test on Bitumen the Source of Bitumen is S-65 Grade

Average penetration of Bitumen for the given bitumen source is 63.33

Penetration of Bitumen source = $\frac{\mathbf{68+62+60}}{\mathbf{3}}$ = 63.33

Input parameters for flexible pavement and rigid pavement:

Design of low traffic volume rural roads with flexible pavements in India is carried out according to the guidelines of the Indian Roads Congress given in IRC: SP: 72-2007 and IRC: SP: 77-2008.

The minimum wheel load for design of rural roads is considered to be 30KN or 3 tons and minimum tyre pressure 0.5MPa and maximum wheel load if any possibility of traffic consisting of mini-trucks and buses a design wheel load of 50KN or 5.20 tons with minimum tyre pressure of 0.7MPa should be considered. As per IRC: SP: 62-2004. The values of elastic modulus of concrete to be taken $3x10^4$MPa, coefficient of thermal expansion of concrete is $10x10^{-6}$per ^{0}c and Poisson's ratio of cement concrete is 0.15

As a research a test load of 100 Kilonewtons or 10 tons was applied on both the flexible and rigid pavements

Plaxis Analysis

PLAXIS is a finite element package that has been developed specifically for the analysis of deformation and stability in geotechnical engineering projects. The simple grap 1hical input procedures enable a quick generation of complex finite element models and the enhanced output facilities provides a detail presentation of computational results. The calculation itself is fully automated and based on robust numerical procedures.

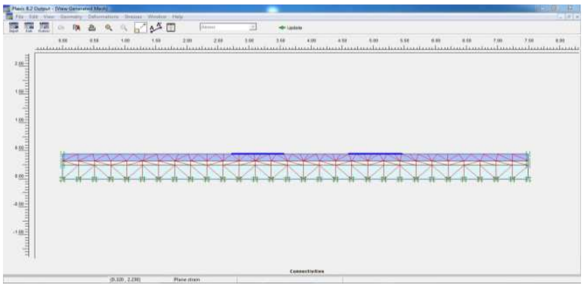

Figure 1: Assigning the Flexible Pavement Layers and Generation of Mesh

The roadway width of 7.50 meters and carriage way width of 3.75 meters it consists of three layers in flexible pavement design as per IRC:SP:72-2007 (layer 1) Thickness of improved sub grade and granular sub-base of 200mm thick (layer 2) Thickness of gravel 100mm thick and (layer 3) Thickness of bituminous surface 75mm thick the total thickness of flexible pavement is 375mm thick

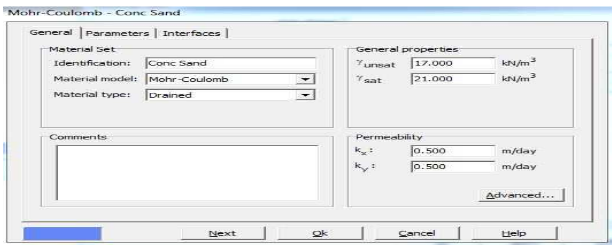

Figure 2: Assigning the Engineering and Geotechnical Properties on the Pavement Layers

Assigning the standard engineering and geotechnical properties on the pavement layers from the plaxis parameters for the selected pavement layers

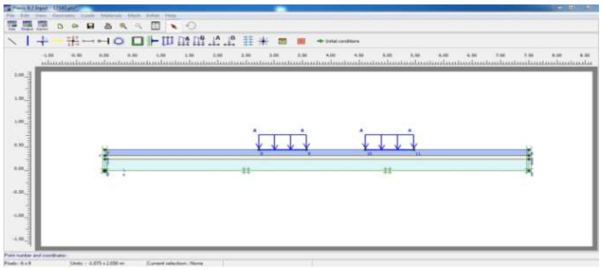

Figure 3: Generation of Standard Fixities and Application of Load on the Plates

The generation of Standard fixities and application of test load on the plates. The minimum clearance between the road face of the kerb and the outer edge of the wheel should be 1.2 m and width of the wheel is as 0.86 m the figure the plates represented on the top layer of the pavement.

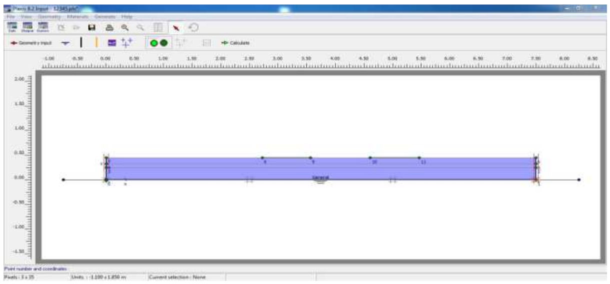

Figure 4: Changing the Geometry and Ground Water Conditions in the Pavement Layers

The geometry and ground water conditions in the pavement layers should be removed

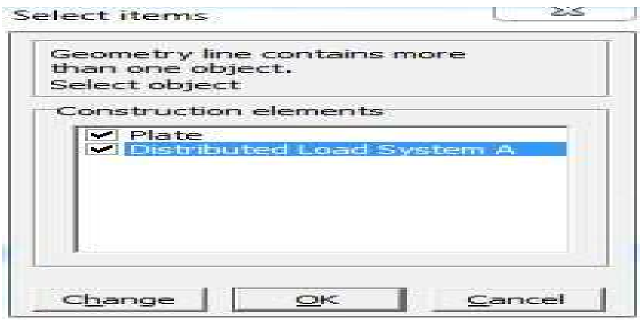

Figure 5: Application of Test Load on the Selected Plates Uniformly Distributed Load of 10 Tons

Assigning the uniform distributed load on the plates so that it can be tested for further tested for deflection, stress and strain in the pavement layers

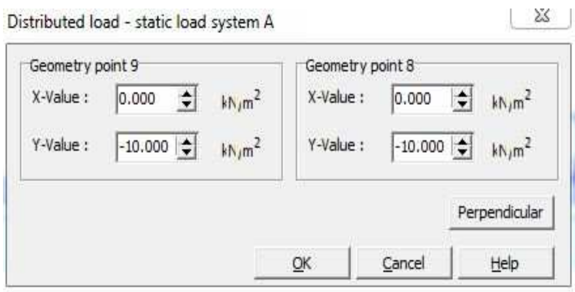

Figure 6: Assigning the Tested Load of 10 Tons in –Y Direction

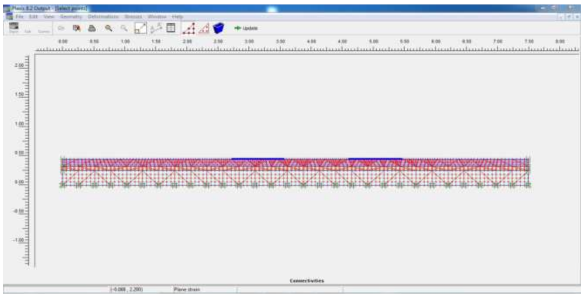

Figure 7: To Find the Stress Generates in the Pavement Layers Assign the Stress Points Below the Plates as Shown in Figure

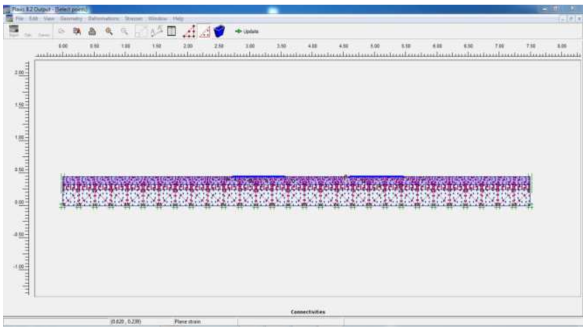

Figure 8: To Find the Strain Generates in the Pavement Layers Assign the Stress Points Below the Plates as Shown in Figure

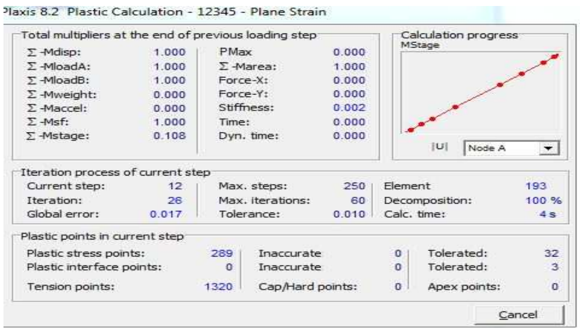

Figure 9: After Assigning the Stress and Strain Points Select The Calculation and Load Analysis of Pavement

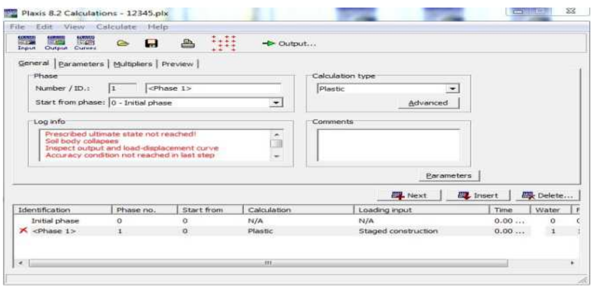

Figure 10: Calculated Output of the Flexible Pavement

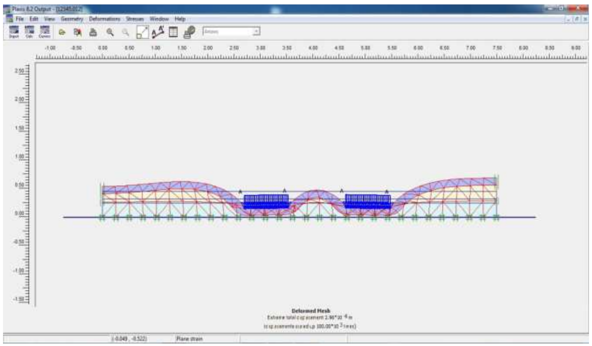

Figure 11: Representing the Total Deformation of the Bottom Layers

Figure-11 Representing the total deformation of the bottom layers in the flexible pavement due to the test load of 10 tons The minimum wheel load for design of rural roads is considered to be 30KN or 3 tons As per IRC: SP: 72-2007

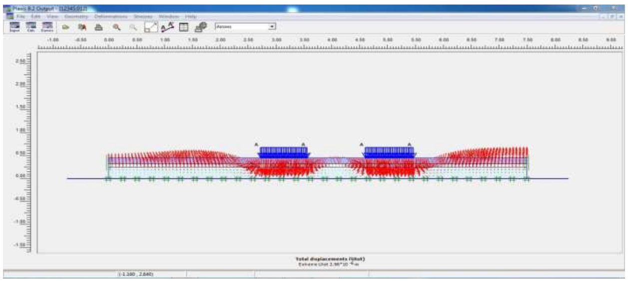

Figure 12: Representing the Total Displacement of the Bottom Layers

Figure-12 Representing the total displacement of the bottom layers in the flexible pavement due to the test load of 10 tons The minimum wheel load for design of rural roads is considered to be 30KN or 3 tons As per IRC: SP: 72-2007

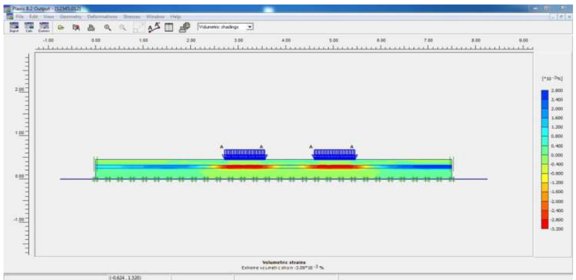

Figure 13: Representing the Volumetric Strain in the Layer

Figure-13 Representing the volumetric strain in the (layer 2) in the flexible pavement due to the test load of 10 tons it is shown in red color

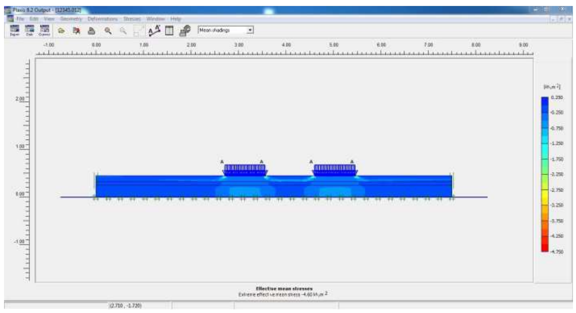

Figure 14: Representing the Effective Mean Stress

Figure-14 Representing the effective mean stress of the flexible pavement it shows satisfactory result of the flexible pavement in all the layers due to the test load of 10 tons.

CONCLUSIONS

From the analysis by Plaxis software the pavement have satisfactory bearing capacity upto 5KN. According to IRC: SP :72-2007, the allowable bearing capacity is 3 KN, but as a research work it have been tested for various increasing loads the pavement have lost its emgimeering properties when it reaches a load of 10 KN. The pavement can resist the load of 10KN if the thickness of sub-layers is increased.

REFERENCES

1. *Rafiqul A. Tarefder, Nayansaha, Jerome W. Hall, and Percy, T. "Evaluating weak subgrade for pavement design and performance prediction". Journel of Geo-Engineering Vol. 3, No 1, 2008.*
2. *Sarna, A. C., Jain, P. K. and Chandra, G. "Capacity of urban roads-A case study of Delhi and Bombay", Highway Research Bulletien, No.4, Indian Road congress, New Delhi, 1989.*
3. *Saurabh Jain, Joshi, Y. P. and Goliya, S. S. "Design of Rigid and Flexible Pavements By Various Methods & Their Cost Analysis of Each Method" , Int. Journal of Engineering Research and Application , Vol. 3, Issue 5, 2013.*
4. *Yagar, S. and Aerde, M. V, "Geometric and Environmental Effects on Speeds of 2-Lane Highways" Transportation Research - A Vol. 17 A, No. 4, PP. 315-325, 1983.*
5. *Chandra, S. and Sikdar, P. K. "Factors Affecting PCU in Mixed Traffic Situation in Urban Roads, Road Transport Research, Vol. 9, No. 3, Australian Road Research Borad, pp 40-50, 2000.*
6. *Highway Capacity Maual, Transportation Research Board, Special Report 209, Fourth Edition, Washington D. C., 2000.*
7. *Brushapathi, KVRDN and NarasingaRao, BND "Pavementr Design of National Highway A Case Study on Reducing Pavement Thickness", International Journey of Engineering Research and Application, Vol. 2, Issue4, pp 1000-1003, 2012.*
8. *Methods of Test for Soils; Part 9 –Determination of Dry Density-Moisture Content Relation by Constant Mass of Soil Method, Indian standard code 2270.16, 1983.*